EPA Initial Thoughts on SAB 7-22-15 Deliberative Draft Appendices A-C

EPA attempt at reconciling notational differences

One of the very useful improvements included in the Alternative Framework presented in the 7-22-15 versions of Appendices A-C is an explicit and clear way of thinking about and notating different treatments of time. Upon reading the earlier 6-22-15 draft of Mark Harmon's Alternative Framework, and initial drafts of Appendices A and B, EPA found the essential ideas presented very promising, however the notational differences and different ways of discussing variables across the documents had the potential to lead to confusion. For the variables *NBE*, *PGE* and *BAF* the *Δt, t, Σt* notation provides the most clarity flux in a particular year *t*, cumulative stock in a particular year *t*, and sum of cumulative stocks over an interval 0 to *t* compared to the notation used elsewhere in the drafts. In the spirit of, "avoiding confusion and talking and talking at cross purposes," EPA attempted to reconcile the notational differences. This effort was completed just ahead of receipt of the 7-22-15 draft of Appendices A-C. Reassuringly, the equations and notation and equations generated by EPA were remarkably similar to those in the 7-22-15 version of Appendix A. Aside from some minor formatting differences, EPA also considered explicitly indexing over *i* feedstocks, *r* regions, and *j* firms. While this additional notation is not needed for conveying the essential ideas presented in Appendices A-C, explicitly considering these details does lead to important questions of how the Alternative Framework could be applied, and potential linkages to other parts of the charge questions. For that reason, EPA's version of these equations is reproduced below.

$PGE_{B,\Delta t}^{i,r}$ total end point or stack emissions in year *t* associated with the increased use of feedstock *i* sourced from region *r* in the policy case, given boundary conditions *B*, measured in units *tons/year*.

$$PGE_{B,\Delta t}^{i,r} = \left(PGE_{B,t}^{i,r} - PGE_{B,t-1}^{i,r}\right) \tag{1}$$

$PGE_{B,t}^{i,r}$ cumulative total end point or stack emissions through year *t* associated with the increased use of feedstock *i* sourced from region *r* in the policy case, given boundary conditions *B*, measured in units *tons*.

$$PGE_{B,t}^{i,r} = \sum_{t=0}^{t} PGE_{B,\Delta t}^{i,r} \tag{2}$$

$PGE_{B,\Sigma t}^{i,r}$ the sum over the interval from the implementation of the policy (*t=0*) through year *t*, of cumulative total end point or stack emissions through each year *t* associated with the increased use of feedstock *i* sourced from region *r* in the policy case, given boundary conditions *B*, measured in units $tons \cdot years$.

$$PGE_{B,\Sigma t}^{i,r} = \sum_{t=0}^{t} PGE_{B,t}^{i,r} = \sum_{a=0}^{t} \left[PGE_{B,\Delta a}^{i,r} \cdot (t-a)\right] \tag{3}$$

$NBE^{i,r}_{B,\Delta t}$ the change between year *t-1* and *t* in the difference between terrestrial carbon stocks in the reference and policy cases associated with the increased use of feedstock *i* sourced from region *r* in the policy case, given boundary conditions *B*, measured in units *tons/year*.

$$\begin{aligned} NBE^{i,r}_{B,\Delta t} &= \left(NBE^{i,r}_{B,t} - NBE^{i,r}_{B,t-1}\right) \\ &= \left(TC^{Ref,r}_{B,t} - TC^{Pol,r}_{B,T}\right) - \left(TC^{Ref,r}_{B,t-1} - TC^{Pol,r}_{B,t-1}\right) \\ &= \Delta\left(TC^{Ref,r}_{B,t} - TC^{Pol,r}_{B,t}\right) \end{aligned} \tag{4}$$

Where *TC* stands for terrestrial carbon, so:

$TC^{Ref,r}_{B,t}$ is the amount of terrestrial carbon within region *r* given boundary condition *B* in time period *t* in the reference case.

$TC^{Pol,r}_{B,T}$ is the amount of terrestrial carbon within region *r* given boundary condition *B* in time period *t* in the policy case.

$NBE^{i,r}_{B,t}$ the difference between terrestrial carbon stocks in the reference and policy cases in year *t* associated with the increased use of feedstock *i* sourced from region *r* in the policy case, given boundary conditions *B*, measured in units *tons*.

$$\begin{aligned} NBE^{i,r}_{B,t} &= \sum_{t=0}^{t} NBE^{i,r}_{B,\Delta t} \\ &= \left(TC^{Ref,r}_{B,t} - TC^{Pol,r}_{B,t}\right) \\ &= \sum_{t=0}^{t} \Delta\left(TC^{Ref,r}_{B,t} - TC^{Pol,r}_{B,t}\right) \end{aligned} \tag{5}$$

$NBE^{i,r}_{B,\Sigma t}$ the sum over the interval from the implementation of the policy (*t=0*) through year *t*, of the cumulative differences between terrestrial carbon stocks in the reference and policy cases in each year 0 to *t* associated with the increased use of feedstock *i* sourced from region *r* in the policy case, given boundary conditions *B*, measured in units $tons \cdot years$.

$$\begin{aligned} NBE^{i,r}_{B,\Sigma t} &= \sum_{t=0}^{t} NBE^{i,r}_{B,t} \\ &= \sum_{t=0}^{t} \left(TC^{Ref,r}_{B,t} - TC^{Pol,r}_{B,t}\right) \\ &= \sum_{t=0}^{t} \sum_{a=0}^{t} NBE^{i,r}_{B,\Delta a} \\ &= \sum_{t=0}^{t} \sum_{a=0}^{t} \Delta\left(TC^{Ref,r}_{B,a} - TC^{Pol,r}_{B,a}\right) \end{aligned} \tag{6}$$

T the year in which the difference between the reference and the policy case terrestrial carbon stocks stabilize.

$$NBE^{i,r}_{B,\Delta t} \cong 0 \qquad \forall\, t > T \tag{7}$$

The Alternative Framework further define *NBE* in terms of specific carbon pools, including net change in carbon stores of live (*CL*), dead (*CD*), soil (*CS*), products (*CP*), waste pools (*CW*), and transportation loss (*TL*) pools. In the updated notation:

$$NBE_{B,\Delta T}^{i,r} = \big[\Delta\big(CL_{B,t}^{Ref,r} - CL_{B,t}^{Pol,r}\big) + \Delta\big(CD_{B,t}^{Ref,r} - CD_{B,t}^{Pol,r}\big) + \Delta\big(CS_{B,t}^{Ref,r} - CS_{B,t}^{Pol,r}\big) + \Delta\big(CP_{B,t}^{Ref,r} - CP_{B,t}^{Pol,r}\big) + \Delta\big(CW_{B,t}^{Ref,r} - CW_{B,t}^{Pol,r}\big) + \Delta\big(TL_{B,t}^{Ref,r} - TL_{B,t}^{Pol,r}\big)\big] \quad (8)$$

and

$$NBE_{B,T}^{i,r} = \sum_{t=0}^{T} \big[\Delta\big(CL_{B,t}^{Ref,r} - CL_{B,t}^{Pol,r}\big) + \Delta\big(CD_{B,t}^{Ref,r} - CD_{B,t}^{Pol,r}\big) + \Delta\big(CS_{B,t}^{Ref,r} - CS_{B,t}^{Pol,r}\big) + \Delta\big(CP_{B,t}^{Ref,r} - CP_{B,t}^{Pol,r}\big) + \Delta\big(CW_{B,t}^{Ref,r} - CW_{B,t}^{Pol,r}\big) + \Delta\big(TL_{B,t}^{Ref,r} - TL_{B,t}^{Pol,r}\big)\big] \quad (9)$$

and

$$NBE_{B,\Sigma T}^{i,r} = \sum_{t=0}^{T} \big[\big(CL_{B,t}^{Ref,r} - CL_{B,t}^{Pol,r}\big) + \big(CD_{B,t}^{Ref,r} - CD_{B,t}^{Pol,r}\big) + \big(CS_{B,t}^{Ref,r} - CS_{B,t}^{Pol,r}\big) + \big(CP_{B,t}^{Ref,r} - CP_{B,t}^{Pol,r}\big) + \big(CW_{B,t}^{Ref,r} - CW_{B,t}^{Pol,r}\big) + \big(TL_{B,t}^{Ref,r} - TL_{B,t}^{Pol,r}\big)\big] \quad (10)$$

Given the *Δt, t, Σt* versions of *PGE* and *NBE*, the *Δt, t, Σt* versions the *BAF equation can be represented as follows:*

$$BAF_{B,\Delta T}^{i,r} = \frac{NBE_{B,\Delta T}^{i,r}}{PGE_{B,\Delta T}^{i}} \quad (11)$$

or

$$BAF_{B,T}^{i,r} = \frac{NBE_{B,T}^{i,r}}{PGE_{B,T}^{i}} \quad (12)$$

or

$$BAF_{B,\Sigma T}^{i,r} = \frac{NBE_{B,\Sigma T}^{i,r}}{PGE_{B,\Sigma T}^{i,r}} = \frac{NBE_{B,\Sigma T}^{i,r}/T}{PGE_{B,\Sigma T}^{i,r}/T} \quad (13)$$

This Alternative Framework represents four potential improvements over the 2014 framework. First is the explicit methodology for calculating the timeframe *T*. The proposed methodology for determining the time period *T* with clear ties to the behavior of the physical system is an important and useful part of the potential response to the first charge question on temporal scales.

The second potential improvement is the *Σt* approach to calculating the *BAF.* The *Δt* and *t* versions of the *BAF* are consistent with what was presented in the 2014 Framework. The *Σt* approach to the *BAF* represents a novel approach that was not considered in the 2014 Framework. The *Σt* approach by focusing on not just cumulative changes in emissions and terrestrial carbon stocks, but the residence time of those change in the atmosphere, represents an elegant way of considering both the long run equilibrium effects of a policy and the time path of how that long run equilibrium is reached. This is potentially an important and welcome contribution to how temporal scales are considered in response to the first charge question.

The third potential improvement is the explicit usage of carbon pools in the *NBE* calculation. The explicit treatment of carbon pools enhances the clarity of the equation, and more explicitly represents what the 2014 Framework equation was attempting to represent.

The fourth potential improvement is the elimination of the adjustment terms *L* and *P*. This is actually a more subtle change. The 2014 Framework followed the original reference point version of the framework in measuring the additional emissions in the policy case, $PGE_x^{i,r}$, as the amount of biomass feedstock produced at the farm or forest. In application though, the firm was given flexibility to measure the usage of biomass feedstocks at different points (e.g. the factory gate, boiler mouth, or stack emissions). Because firms were allowed to measure biomass feedstock usage at a different point of assessment than the point that was used for calculating the BAF, the *L* term was needed to account for any mass leaving the system between these two points of assessment. By forcing the point of assessment used for firms applying the BAF_x to be the same as the point of assessment used for calculating the BAF_x, the *L* term in the 2014 Framework becomes 1 and drops out of the equations.

Additionally the *P* term was needed in the 2014 Framework because a firm was allowed to measure its biomass feedstock usage before the point at which it actual emissions occur. For example, if a firm measures its feedstock usage as tons entering the boiler mouth, then an adjustment needs to be made to account for the fact that some fraction of those tons will be sequestered as ash and not emitted into the atmosphere. Another example, if a firm measures biomass feedstock usage at the factory gate, but some of the biomass feedstock is turned into pellets that are combusted by another firm, the *P* term was needed to share responsibility for those tons between the firm producing the pellets and the firm that eventually combusts the pellets. From the perspective of modeling the *BAF* the need for this term was less obvious, since the model could clearly capture the entirety of the increase feedstock usage. From the perspective of applying the *BAF* the *P* term was clearly needed, given the construction of the equation, in order to correctly add up the tons feedstock across firms and avoid any double counting or leakages from the system. When the point of assessment for calculating *PGE* for the *BAF* and the point of assessment for firms to measure PGE when applying the *BAF* are both moved to the stack or the end point of the chain of custody where emissions actually occur, there is no need to worry about any mass escaping the system between the point of measurement and the point of emissions, so the *P* term becomes 1 and drops out of the equations. In this sense, by abandoning some of the conventions that were left over from the original reference point approach, and only allowing PGE to represent tons of actual emissions instead of tons of feedstock at different points, the Alternative Framework eliminates the need for *P* and *L*, greatly simplifying the equations and enhancing clarity.

These last two potential improvements are further discussed in the next section, which considers the mapping between the 2014 Framework and the Alternative Framework more explicitly.

Comparison of Alternative Framework & 2014 Framework with implications for L and P

As noted in the introduction to Appendix A, both the 2014 Framework and the proposed Alternative Framework attempt to answer the same question. “Is more or less carbon stored in the system over time compared to what would have been stored in the absence of changes in biogenic feedstock use?” (Environmental Protection Agency, 2014, pp. J-6). This is important to note because it means that the proposed Alternative Framework is not a paradigm shift in how we should think about the problem, but a refinement in how we answer the question.

As shown in equations 8-10, the proposed alternative framework makes the link to terrestrial carbon pools much more explicit than in the 2014 Framework, and this increased clarity is a welcome suggestion. It’s worth noting though that the formulation of NBE in the 2014 Framework was intended to be equivalent to the formulation in equations 8 and 9 in the case where *L=1* and *P=1* (i.e. there are no transportation losses, and no secondary products). From the 2014 Framework (adapted with current notation):

$$NBE_{B,\Delta T}^{i,r} = \left(PGE_{B,\Delta T}^{i,r}\right)\left(GROW_{B,\Delta T}^{i,r} + AVOIDEMIT_{B,\Delta T}^{i,r} + SITETNC_{B,\Delta T}^{i,r} + LEAK_{B,\Delta T}^{i,-r}\right)(L)(P) \qquad \text{(EQ. F.1)}$$

The $\left(GROW_{B,\Delta T}^{i,r} + AVOIDEMIT_{B,\Delta T}^{i,r} + SITETNC_{B,\Delta T}^{i,r} + LEAK_{B,\Delta T}^{i,-r}\right)$ portion of the equation contains all unitless terms that are meant to represent the terrestrial carbon flux per unit of *PGE*, so when multiplied by *PGE*, the *PGE*’s would cancel and what’s left is the terrestrial carbon flux. This cancelling of *PGE* terms was discussed in detail in Appendix F of the 2014 Framework:

> “It is important to note that *GROW, AVOIDEMIT, SITETNC*, and *LEAK* are all unitless.[1] For the purposes of this appendix, we can define our landscape emissions effects terms from the overall *BAF* equation as follows:
>
> $$(GROW + AVOIDEMIT + SITETNC + LEAK) = \left(\frac{G + A + S + Lk}{PGE_0}\right) \qquad \text{(EQ. F.5)}$$
>
> *“*This is merely another way to specify the landscape effect. The original term is a unitless ratio of the contribution of landscape effects on the overall *BAF* value. However, we can also think of each of these elements as being relative to the total amount of biomass that is harvested at the forest or farm (PGE_0). *G, A, S,* and *Lk* are variables that represent the actual tons of landscape net emissions resulting from producing PGE_0 tons of biomass.[2] In that sense, *(G+A+S+Lk)* represents actual net emissions on the landscape caused by a harvest of PGE_0. The landscape-level emissions are normalized by PGE_0 to arrive at the original, unitless term.”

In this sense we can see the correspondence between the carbon pools in the Alternative Framework and the *(G+A+S+Lk)* portion of the NBE_x term from the 2014 Framework. In the alternative framework transportation losses and products are treated just like all of the other carbon pools. One clear advantage of this alternative approach is that in the 2014 Framework, losses are treated as if they are

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[1] However, the framework can be adapted to use units instead of unitless values as needed for a specific application.

[2] Where $GROW = G / PGE_0$; $AVOIDEMIT = A / PGE_0$; $SITETNC = S / PGE_0$; and $LEAK = Lk / PGE_0$.

stack emissions that are released immediately, and products that are not eventually combusted are assumed to be stored indefinitely, whereas the alternative framework captures the time dynamics of loss and product pools. The reason the 2014 included the *L* and *P* terms outside of the portion of the equation that included landscape effects (i.e. terrestrial carbon flux terms, though admittedly the *LEAK* term fits awkwardly with the others in this grouping), had to do with considering not just how BAF values would be calculated based on model runs, but also considering what quantities could be measured, and how the BAF_x would be applied.

The basic idea behind the biomass accounting factor (BAF_x where the subscript x indicates that referring to the variable generically without specifying timeframe, boundary condition, feedstock or region) is to determine how much more or less carbon is stored in the system over time (net biogenic emissions or NBE_x) for a given amount of biogenic feedstock use (potential gross emissions or PGE_x). The unitless biomass accounting factor (BAF_x) can be calculated as the ratio NBE_x over PGE_x based on modeling that compares the terrestrial carbon stocks in a reference case to the terrestrial carbon stocks in a policy case where the amount of additional biomass feedstock used is equal to PGE_x. The BAF_x can then be applied to a particular facility that uses a particular amount of biomass feedstock, by multiplying the BAF_x by the amount of feedstock used to determine the change in carbon stored in the system over time associated with that facility's usage of that particular amount of biomass feedstock.

The essential assumption behind a regional *BAF* approach instead of a source specific *BAF* is that the $BAF_x^{i,r}$ can be calculated at a regional level based on an aggregate increase in biomass feedstock $PGE_x^{i,r}$ sourced from region *r*, and $NBE_x^{i,r}$, the change in terrestrial carbon stocks over time associated with that increase in feedstock usage. Then that regional $BAF_x^{i,r}$ can be applied at a source specific level multiplying $BAF_x^{i,r}$ by $PGE_x^{i,j,r}$ to calculate $NBE_x^{i,j,r}$ the change in terrestrial carbon stocks over time associated with source *j*'s increased use of biomass feedstock *i* sourced from the region *r*.

We modify the *PGE* equations to make this aggregation over *j* sources explicit:

$$PGE^{i,r}_{B,\Delta T} = \sum_{j=1}^{J} PGE^{i,j,r}_{B,\Delta T} = \sum_{j=1}^{J} \left(PGE^{i,j,r}_{B,t} - PGE^{i,j,r}_{B,t-1}\right) \qquad (14)$$

and

$$PGE^{i}_{B,T} = \sum_{j=1}^{J} PGE^{i,j,r}_{B,T} = \sum_{t=0}^{T} \sum_{j=1}^{J} PGE^{i,j,r}_{B,\Delta t} \qquad (15)$$

and

$$PGE^{i}_{B,\Sigma T} = \sum_{j=1}^{J} PGE^{i,j,r}_{B,\Sigma T} = \sum_{j=1}^{J} \sum_{t=0}^{t} PGE^{i,j,r}_{B,t} = \sum_{j=1}^{J} \sum_{t=0}^{t} \sum_{a=0}^{t} \left[PGE^{i,j,r}_{B,\Delta a} \cdot (t-a)\right] \qquad (16)$$

The 2014 Framework needed the term *L* because it assumed that *NBE* was calculated as the change in terrestrial carbon stocks over time associated with increased feedstock usage *as measured at the forest or farm level*, but that in application $PGE_x^{i,j}$ may instead be measured at the source's boiler mouth or stack, so the term *L* was needed to account for any differences between $\sum_{j=1}^{J} PGE_x^{i,j}$ as measured at the source in application, and PGE_x^i as measured at the farm or forest in calculating the *BAF*. This choice of a farm or forest level *PGE* for calculation of the *BAF* may have had its roots in an attempt to be consistent with the original Framework, and its focus on measured instead of modeled quantities. In the Alternative Framework discussed here, PGE_x^i is assumed to be measured as emissions out of the stack instead of feedstock grown on the farm or forest, and the point of assessment for $PGE_x^{i,j}$ is also assumed to be emissions out of the stack, so there is no need for an *L* term (*L*=1). Upon consideration here, this is a welcome simplification. The models can certainly calculate *BAF*s based on stack emission *PGE*s, and sources should be able to measure their stack emissions associated with biomass feedstock usage, so for the future anticipated baseline approach, the complication introduced by *L* should not be necessary.

The 2014 Framework included the *P* term to account for products that were produced downstream of the point of assessment where a source measured $PGE_x^{i,j}$. For example, if a source measured $PGE_x^{i,j}$ as the tons of biomass feedstock at the boiler mouth, but some of the tons of carbon that entered the boiler mouth were converted into products (either stored in product pools, or sold to another source that would eventually combust the product), then an adjustment needed to be made in order to ensure that the source was not held accountable for emissions that either did not occur, or were the responsibility of another source downstream. Once again, the Alternative Framework offers a welcome simplification. By forcing the point of assessment to be stack emissions, there are no products or losses generated downstream of the point of assessment, so there is no need for an adjustment term that indicates what share of the measured feedstock quantity $PGE_x^{i,j}$ eventually becomes a stack emission that the source is responsible for, and what share is embedded in products that are either stored or combusted by another source.[3] Product pools are dealt with explicitly in their carbon pool, and there are no secondary products that are eventually combusted downstream of the point of assessment.

The introduction of the *L* and *P* terms in the 2014 Framework was needed because the equations were designed to be flexible enough to allow sources to measure their use of biomass feedstock at the factory gate, boiler mouth, or as emissions out of the stack, and increased biogenic feedstock usage PGE_x^i that would be run through the model to calculate the BAF_x^i was intended to be measured as the amount of feedstock grown at the farm or forest. These decisions were consistent with how the original Framework was constructed. By abandoning this flexibility, and specifying that *PGE* in all forms always be measured as end point emissions that a source is responsible for, and explicitly tracking product an transportation loss pools, the Alternative Framework gains a considerable amount of simplicity and transparency.

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[3] The one case where there is a slight difference between the approach here of treating the point of assessment as stack emissions and calculating and using stack emissions for *PGE* in the *BAF* calculation, and the approach taken in the 2014 Framework is the case outlined in example 5 of Appendix F of the 2014 Framework. In this case there was a source that produces emissions and a product that was used by a downstream source that also generates emissions. If there are losses that occur downstream of the first source, but upstream of the second source, the equation presented in example 5 would hold the downstream source accountable for those losses, but not the upstream source. In the Alternative Framework version, all sources would be equally accountable for the losses according to their share of potential gross emissions. The equation required to deal with this hypothetical case in example 5 was particularly complex, and the benefits of the simplified equation in the alternative approach likely outweigh any benefits from the more complex equation in this hypothetical case.

Questions raised from considering the Alternative Framework

Q: Do we need to explicitly consider the impact increased feedstock usage in region r has on all regions (e.g. $BAF_{B,\Sigma T}^{i,r} = \frac{\sum_{r=1}^{R} NBE_{B,\Sigma T}^{i,r}}{PGE_{B,\Sigma T}^{i,r}}$)? If so, could this be done by running a policy case that increases feedstock usage in only one region, so the impacts in other regions are clearly due to the increased feedstock usage in the analyzed region? Or would this distort the results from what would be expected if all regions were allowed to produce the feedstock in order to meet the increased demand. And in a scenario where the increased demand is applied to multiple regions, how should impacts be shared out among regions?

Q: Analogous to the question of modeling different regions simultaneously or in isolation is the question of how different feedstocks should be modeled (see charge questions 2 d & e). Note that in the above notation used in EPA's representation of the Alternative Framework equations, *PGE, NBE,* and *BAF* are all indexed over *i* feedstocks. Clearly *PGE,* and *BAF* require this indexing, as potential gross emissions are necessarily associated with a specific feedstock, and *BAF* values will need to be feedstock specific. It is a little less clear how a feedstock specific *NBE* should be calculated. $NBE_{B,T}^{i,r}$ is meant to represent the difference between terrestrial carbon stocks in the reference and policy cases in year *t* **associated with the increased use of feedstock *i*** sourced from region *r* in the policy case, given boundary conditions *B*, measured in units *tons*. In the *NBE* equations above, the terrestrial carbon stocks (TC) are not indexed by *i* feedstocks, since it is less clear how that should be interpreted or calculated. If the policy case is an increase in demand for feedstock *i*, then it is clear that the entire difference between reference and policy case terrestrial carbon stocks is associated with the use of feedstock *i*, and the indexing makes sense. If the policy case is an increased demand for all biomass feedstocks, then it is less clear how changes in terrestrial carbon stocks should be attributed to different feedstocks. In answering charge question 2, it would be very helpful if the panel considers the implications those answers have in calculating *BAF* values using the proposed Alternative Framework.